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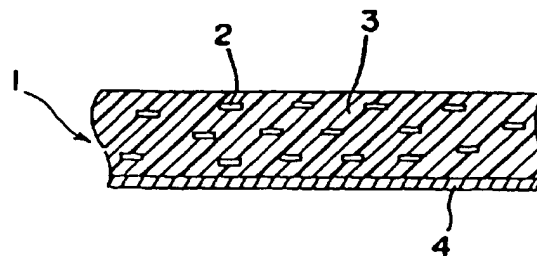
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(54) **COMPOUND MAGNETIC MATERIAL AND ELECTROMAGNETIC INTERFERENCE SUPPRESSOR**

(57) A thin electromagnetic interference suppressing body effective for electromagnetic interference suppression at a microwave band. As a material of the electromagnetic interference suppressing body, there is provided a composite magnetic body formed by bonding powder made of a semi-hard magnetic material by an organic bonding agent and having a high magnetic loss at the microwave band. As the semi-hard magnetic material, a metallic magnetic body, such as Fe-Co-Mo alloy, Co-Fe-Nb alloy or Fe-Co-V alloy, or an oxide magnetic body, such as  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> or Co-Ti substituted Ba ferrite, can be used. Further, as an example of the organic bonding agent, polyurethane resin can be cited.

Fig. 1



## Description

## Technical Field

5 The present invention relates to an electromagnetic interference suppressing body for a high frequency region, particularly, a microwave band, and in particular, to a composite magnetic material therefor.

## Background Art

10 In recent years, the spread of electronic devices, including digital electronic devices, using high frequency waves has been advanced and, among them, the spread of mobile communication devices using quasi-microwave bands or microwave bands has been remarkable. In those mobile communication devices represented by portable telephones, demands for reduction in size and weight are so great that high-density mounting of electronic components has become the greatest technical problem. Accordingly, since the electronic components, the printed wiring, the inter-module wiring, etc. which are mounted overcrowdedly, approach to each other extremely, and further since the speed-up of the signal processing speed is schemed, the inter-line coupling due to the electrostatic coupling and/or the electromagnetic coupling becomes large and interference due to radiant noise or the like is caused, so that not a few situations have occurred wherein normal operations of the devices are impeded.

Conventionally, against such so-called high-frequency electromagnetic interference, a measure has been mainly taken to apply a conductor shield.

However, since the conductor shield is an electromagnetic interference countermeasure utilizing reflection of electromagnetic waves due to impedance mismatch relative to the space, it can provide a shielding effect but has a drawback to promote the electromagnetic coupling due to reflection from an undesired radiation source. For solving such a drawback, it could be considered effective as a secondary electromagnetic interference countermeasure to use a magnetic loss of a magnetic body, that is, an imaginary part permeability  $\mu''$  so as to suppress the undesired radiation.

It has been known that the absorption efficiency of undesired radiation increases corresponding to a magnitude of  $\mu''$  in a frequency range where  $\mu'' > \mu'$ . Accordingly, for obtaining a large magnetic loss at a microwave band, it is necessary to realize a characteristic where the real part permeability attenuates due to the magnetic resonance at a VHF band (30MHz to 300MHz), a quasi-microwave band (300MHz to 3GHz) or a low-frequency side of a microwave band (3GHz to approximately 10GHz).

Therefore, it is an object of the present invention to provide a composite magnetic body where the magnetic resonance appears in a range from VHF band to microwave band and, as a result, a magnetic loss at the microwave band is large (that is, an imaginary part permeability  $\mu''$  is large). It is another object to provide an electromagnetic interference suppressing body using such a composite magnetic body.

## Disclosure of the Invention

According to the present invention, there is obtained a composite magnetic body characterized in that semi-hard magnetic powder is bonded by an organic bonding agent, and a magnetic resonance appears in a range from VHF band to microwave band.

The foregoing semi-hard magnetic powder is characterized in that a coercive force  $H_c$  thereof is 10 to 300Oe.

The foregoing semi-hard magnetic powder is characterized by having a flat or needle shape and being oriented/aligned in the composite magnetic body.

As a material of the foregoing semi-hard magnetic powder, a magnetic metal alloy, such as Fe-Co-Mo alloy, Co-Fe-Nb alloy or Fe-Co-V alloy, can be cited.

Further, as another material of the foregoing semi-hard magnetic powder, an oxide magnetic body, such as  $\gamma$ - $Fe_2O_3$  (maghemite) or Co-Ti substituted Ba ferrite, can be cited.

According to the present invention, there is obtained an electromagnetic interference suppressing body using, as a material thereof, the foregoing composite magnetic body, and having a large magnetic loss at a microwave band.

## Brief Description of the Drawings

Fig. 1 is a diagram schematically showing a section of a composite magnetic body of the present invention;

Fig. 2 is a diagram showing  $\mu$ -f characteristics of sample 1 and sample 4 of a composite magnetic body according to the present invention; and

Fig. 3 is a schematic diagram showing an evaluation system used for characteristic evaluation of an electromagnetic interference suppressing body using a composite magnetic body sample of the present invention.

## Best Mode for Carrying Out the Invention

In the present invention, a semi-hard magnetic material with a coercive force  $H_c$  of 10 to 300 Oe, for example, a metallic magnetic body, such as Fe-Co-Mo alloy, Co-Fe-Nb alloy or Fe-Co-V alloy, or an oxide magnetic body, such as  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> or Co-Ti substituted Ba ferrite, is used as a raw material.

When the raw material is the metallic magnetic body, coarse powder is obtained by a mechanical milling method, an atomizing method or the like, then flattened using a wet mill such as an attriter, and thereafter bonded using an organic bonding agent so as to obtain a composite magnetic body. On the other hand, when the raw material is the oxide magnetic body, flat or needle-shaped fine powder is directly prepared by a crystallizing method, such as a hydro-thermal synthesis method or the like, and then bonded using an organic bonding agent so as to obtain a composite magnetic body.

For obtaining a large imaginary part permeability  $\mu''$  in the foregoing composite magnetic body, the magnetic powder is flattened or needle-shaped so as to have a thickness equal to or less than a skin depth, an aspect ratio of the flattened or needle-shaped soft magnetic material is set to be approximately not less than 10 for setting a diamagnetic field coefficient  $N_d$  to be approximately 1, and the magnetic powder is oriented/aligned in the composite magnetic body. Here, the skin depth  $\delta$  is given by the following equation.

$$\delta = (\rho / \pi \mu f)^{1/2}$$

In the foregoing equation,  $\rho$  represents resistivity,  $\mu$  represents permeability and  $f$  represents frequency. Here, although values differ depending on target frequencies, it is one of the easiest means, for obtaining desired skin depth and aspect ratio, to specify the mean particle diameter of the starting material powder when the metallic magnetic body is used.

As typical milling means which can be used for flattening the metallic magnetic material, a ball mill, an attriter, a pin mill, etc. can be cited. As long as the thickness and the aspect ratio of the magnetic powder satisfying the foregoing conditions can be obtained, there is no limitation on the milling means.

Further, for ensuring electrical insulation among individual magnetic powder in the composite magnetic body to give a function as an electrical insulator to the composite magnetic body even in a high-density loading state of the magnetic powder, it is preferable to form dielectric layers on the surfaces of the magnetic powder of an alloy material. The dielectric layers can be realized as oxide layers of metal elements constituting the alloy by oxidizing the surfaces of the metallic magnetic powder. As one example of a means for oxidizing the surfaces of the metallic powder, it is preferable, in view of easiness, stability and safety of a control, to carry out an oxidizing process by a liquid-phase acid removing method or a gas-phase acid removing method which introduces nitrogen-oxygen mixed gas at a controlled oxygen partial pressure in a hydrocarbon organic solvent or an atmosphere of inert gas, particularly for the metallic powder having high activity and relatively small size.

When the oxide magnetic powder is used as the magnetic powder, it is not necessary to be processed by the foregoing surface oxidizing process because it has high electrical resistance per se.

As an organic bonding agent to be used as one constituent component of the composite magnetic body of the present invention, polyester resin, polyethylene resin, polyvinyl chloride resin, polyvinyl butyral resin, polyurethane resin, cellulose resin, ABS resin, nitrile-butadiene rubber, styrene-butadiene rubber, epoxy resin, phenol resin, amide resin, imide resin or copolymers thereof can be cited.

There is no particular limitation on the foregoing means for kneading/dispersing the semi-hard magnetic powder and the organic bonding agent to obtain the composite magnetic body, and a preferable method may be selected using properties of a bonding agent to be used and facility of processes as criteria.

As means of orienting/aligning the magnetic particles in the kneaded/dispersed magnetic mixture, there are a method using a shearing stress and a method using a magnetic field orientation, either of which may be used.

For explaining a structure of the composite magnetic body of the present invention, its section is schematically shown in Fig. 1. Referring to the same figure, a composite magnetic body 1 is formed by dispersing flat semi-hard magnetic particles 2 into a layer of an organic bonding agent 3 and bonding them. On the other hand, 4 denotes a support provided when the strength is required upon handling or when a shield characteristic is required as an electromagnetic interference suppressing body in addition to a high-frequency magnetic loss characteristic. It may be an insulating plate when an improvement in mechanical strength is only aimed. On the other hand, when the shield characteristic is required, it is necessary to consider an electrical characteristic and to select a material excellent in electrical conductivity. A copper plate in Fig. 3, which will be described later, is also used as a shield member with high electrical conductivity.

Hereinbelow, more concrete examples will be described.

First, a plurality of ingots of Fe-Cu-Mo alloy, Co-Fe-Nb alloy and Fe-Co-V alloy were prepared and coarsely milled by a stamp mill, then subjected to grinding processes under various conditions using an attriter. Further, while introduc-

ing nitrogen-oxygen mixed gas at a 35% oxygen partial pressure, they were agitated for 8 hours in a hydrocarbon organic solvent and subjected to a liquid-phase acid removing process. Thereafter, a classifying process was carried out to obtain a plurality of flat magnetic powder samples having different coercive forces  $H_c$ . As a result of analyzing the surfaces of the obtained powder, the generation of metal oxides was clearly confirmed so that the presence of oxide films on the surfaces of the sample powder was confirmed.

On the other hand,  $\gamma\text{-Fe}_2\text{O}_3$  powder and Co-Ti substituted Ba ferrite powder were prepared by the hydrothermal synthesis method so as to obtain oxide magnetic powder samples.

Using these powders, below-described composite magnetic body samples were prepared to examine  $\mu$ -f characteristics.

For the measurement of the  $\mu$ -f characteristics, the composite magnetic body samples used were processed into toroidal shapes. By inserting it into a test fixture forming a one-turn coil to measure its impedance,  $\mu'$  and  $\mu''$  were derived.

#### [Sample 1]

A semi-hard magnetic paste was prepared which had the following composition, and formed into a film by a doctor blade process. After applying hot pressing thereto, curing was carried out at 85°C for 24 hours to obtain sample 1.

The obtained sample 1 was analyzed using a scanning electron microscope and it was confirmed that the particle alignment was in an in-surface direction of the sample.

Flat semi-hard magnetic body (Fe-Cu-Mo alloy) Fine powder A	95 weight parts
Mean particle diameter:	$\varnothing 20\mu\text{m} \times 0.3\mu\text{m}^1$
Coercive force $H_c$ :	250e
Polyurethane resin	8 weight parts
Curing agent (isocyanate compound)	2 weight parts
Solvent (mixture of cyclohexanone and toluene)	40 weight parts

#### [Sample 2]

A semi-hard magnetic paste was prepared which had the following composition, and formed into a film by a doctor blade process. After applying hot pressing thereto, curing was carried out at 85°C for 24 hours to obtain sample 2.

The obtained sample 2 was analyzed using a scanning electron microscope and it was confirmed that the particle alignment was in an in-surface direction of the sample.

Flat semi-hard magnetic body (Co-Fe-Nb alloy) Fine powder B	95 weight parts
Mean particle diameter:	$\varnothing 20\mu\text{m} \times 0.3\mu\text{m}^1$
Coercive force $H_c$ :	320e
Polyurethane resin	8 weight parts
Curing agent (isocyanate compound)	2 weight parts
Solvent (mixture of cyclohexanone and toluene)	40 weight parts

#### [Sample 3]

A semi-hard magnetic paste was prepared which had the following composition, and formed into a film by a doctor blade process. After applying hot pressing thereto, curing was carried out at 85°C for 24 hours to obtain sample 3.

The obtained sample 3 was analyzed using a scanning electron microscope and it was confirmed that the particle alignment was in an in-surface direction of the sample.

Flat semi-hard magnetic body (Fe-Co-V alloy) Fine powder C	95 weight parts
Mean particle diameter:	$\varnothing 30\mu\text{m} \times 0.4\mu\text{m}^{\dagger}$
Coercive force Hc:	130Oe
Polyurethane resin	8 weight parts
Curing agent (isocyanate compound)	2 weight parts
Solvent (mixture of cyclohexanone and toluene)	40 weight parts

## [Sample 4]

A semi-hard magnetic paste was prepared which had the following composition, and formed into a film by a doctor blade process. After drying it in a magnetic field in an in-surface direction of a sample, hot pressing was applied thereto and curing was carried out at 85°C for 24 hours to obtain sample 4.

The obtained sample 4 was analyzed using a vibrating type magnetometer and it was confirmed that a magnetization easy axis was in an in-surface direction of the sample.

Needle-shaped semi-hard magnetic body ( $\gamma\text{-Fe}_2\text{O}_3$ ) Fine powder D	95 weight parts
Mean particle diameter:	$\varnothing 0.1 \times 0.8\mu\text{m}^{\dagger}$
Coercive force Hc:	270Oe
Polyurethane resin	8 weight parts
Curing agent (isocyanate compound)	2 weight parts
Solvent (mixture of cyclohexanone and toluene)	40 weight parts

## [Sample 5]

A semi-hard magnetic paste was prepared which had the following composition, and formed into a film by a doctor blade process. After drying it in a magnetic field in an in-surface direction of a sample, hot pressing was applied thereto and curing was carried out at 85°C for 24 hours to obtain sample 5.

The obtained sample 5 was analyzed using a scanning electron microscope and it was confirmed that the particle alignment was in a direction perpendicular to an in-surface direction of the sample, and it was further analyzed using a vibrating type magnetometer and it was confirmed that a magnetization easy axis was in the in-surface direction of the sample.

Flat semi-hard magnetic body (Co-Ti substituted Ba ferrite) Fine powder E	95 weight parts
Mean particle diameter:	$\varnothing 1\mu\text{m} \times 0.3\mu\text{m}^{\dagger}$
Coercive force Hc:	295Oe
Polyurethane resin	8 weight parts
Curing agent (isocyanate compound)	2 weight parts
Solvent (mixture of cyclohexanone and toluene)	40 weight parts

Magnetic resonance frequencies  $f_r$  and imaginary part permeabilities  $\mu''$  measured with respect to the foregoing respective samples are shown in Table 1 below.

[Table 1]

	Magnetic Resonance Frequency $f_r$	Imaginary Part Permeability $\mu''$
Sample 1	80MHz	4.1
Sample 2	90MHz	3.5
Sample 3	400MHz	2.3
Sample 4	850MHz	1.5
Sample 5	1.1GHz	1.3

Fig. 2 shows  $\mu$ - $f$  characteristics of sample 1 and sample 4. The other samples exhibited characteristics approximately within these frequency ranges.

As seen from the foregoing Table 1 and Fig. 2, according to the present invention, there can be obtained the composite magnetic materials with high magnetic losses at the microwave band.

Using the foregoing samples, electromagnetic interference suppressing effects thereof were measured using an evaluation system as shown in Fig. 3.

Here, a composite magnetic body sample 10 having a thickness of 2mm and a length of each side being 20cm was backed with a copper plate 11 so as to prepare an electromagnetic interference suppressing body sample. An electromagnetic wave was radiated to the sample from an electromagnetic wave generator 12 via a micro-loop antenna 13 having a loop diameter of 1mm, and a reflected wave from the electromagnetic interference suppressing body sample was received at an antenna 14 of the same size and shape so as to measure the strength of the reflected wave by a network analyzer (electromagnetic field strength measuring device) 15.

The results are shown in Table 2 along with the surface resistances.

[Table 2]

	Sample 1	Sample 4
Surface Resistance ( $\times 10^7 \Omega$ )	5.8	4.3
Signal Attenuation (dB) (at 8GHz)	7.9	5.7

Here, the surface resistances are measured values according to the ASTM-D-257 method. Values of the electromagnetic interference suppressing effect represent signal attenuation when the copper plate is set to a reference (0dB).

From the foregoing Table 2, the following effects are evident.

Specifically, according to the composite magnetic body of the present invention, the value of the surface resistance is  $10^7$  to  $10^8 \Omega$ . Therefore, by using the magnetic powder oxidized at least on the surfaces thereof, the high insulation can be given to the composite magnetic body so that the surface reflection of the electromagnetic waves due to impedance mismatch as observed with respect to the conductor, the bulk metallic magnetic body or the like, can be suppressed.

Further, it is understood that the composite magnetic body of the present invention has the excellent electromagnetic interference suppressing effect at the microwave band.

As described above, according to the present invention, there can be obtained the composite magnetic body in the form of the semi-hard magnetic powder bonded by the organic bonding agent, which has the high magnetic loss at the microwave band and thus can suppress the electromagnetic waves at the microwave band. Therefore, using this composite magnetic body, the thin electromagnetic interference suppressing body effective at the microwave band can be obtained.

#### Industrial Applicability

The flexibility can be easily given to the composite magnetic body and the electromagnetic interference suppressing body of the present invention as seen from the constituent components thereof. Thus, it is possible to deal with a complicated shape or strict requirements for vibration and shock resistance.

Claims

1. A composite magnetic body characterized in that semi-hard magnetic powder is bonded by an organic bonding agent, and a magnetic resonance appears in a range from VHF band to microwave band.
- 5 2. The composite magnetic body as recited in claim 1, characterized in that a coercive force H<sub>c</sub> of said semi-hard magnetic powder is 10 to 300Oe.
3. The composite magnetic body as recited in either of claims 1 and 2, characterized in that said semi-hard magnetic powder has a flat or needle shape and is oriented/aligned in said composite magnetic body.
- 10 4. The composite magnetic body as recited in either of claims 2 and 3, characterized in that said semi-hard magnetic powder is Fe-Co-Mo alloy powder.
- 15 5. The composite magnetic body as recited in either of claims 2 and 3, characterized in that said semi-hard magnetic powder is Co-Fe-Nb alloy powder.
6. The composite magnetic body as recited in either of claims 2 and 3, characterized in that said semi-hard magnetic powder is Fe-Co-V alloy powder.
- 20 7. The composite magnetic body as recited in either of claims 2 and 3, characterized in that said semi-hard magnetic powder is  $\gamma$ -Fe<sub>2</sub>O<sub>3</sub> (maghemite) powder.
8. The composite magnetic body as recited in either of claims 2 and 3, characterized in that said semi-hard magnetic powder is Co-Ti substituted Ba ferrite powder.
- 25 9. An electromagnetic interference suppressing body using, as a material thereof, the composite magnetic body as recited in any of claims 1 to 8, and having a large magnetic loss at a microwave band.

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Fig. 1

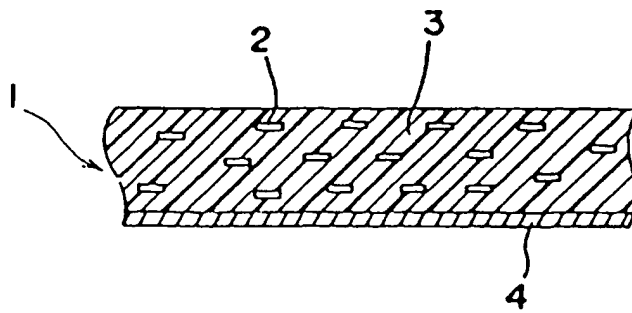


Fig. 2

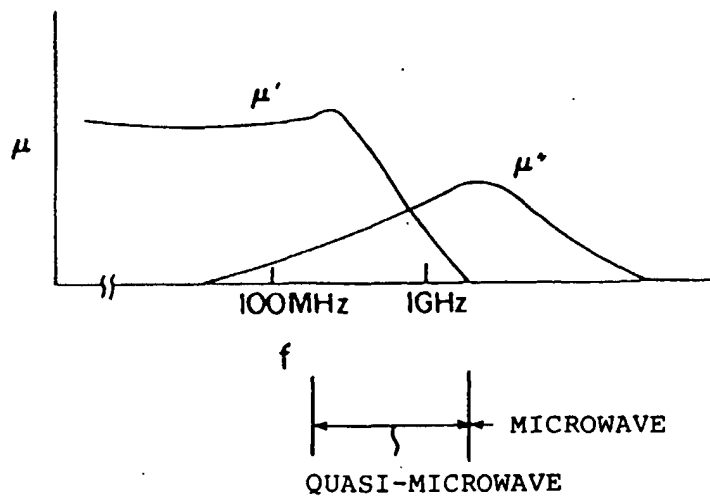
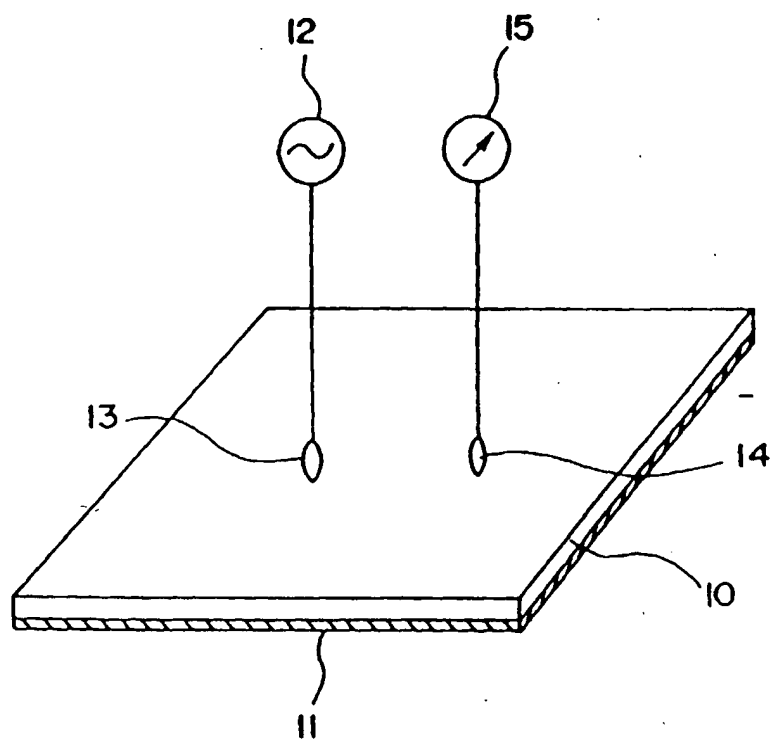




Fig. 3



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP97/03396

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> Int. C1 <sup>6</sup> H01F1/00, H01Q17/00, H05K9/00 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) Int. C1 <sup>6</sup> H01F1/00, H01Q17/00, H05K9/00 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926 - 1997 Kokai Jitsuyo Shinan Koho 1971 - 1997 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 4-11624, A (Toda Kogyo Corp.), January 16, 1992 (16. 01. 92), Claims; page 3, lower right column, lines 13 to 18 (Family: none)	1-3, 7, 9
Y	JP, 57-180206, A (Great Britain), November 6, 1982 (06. 11. 82), Claims (Family: none)	1-3, 8, 9
Y	JP, 62-213101, A (TDK Corp.), September 19, 1987 (19. 09. 87), Claims (Family: none)	4 - 6
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search December 8, 1997 (08. 12. 97)		Date of mailing of the international search report December 16, 1997 (16. 12. 97)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.		Authorized officer Telephone No.

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